INVESTIGATIONS OF SPENT FUEL CASK RESPONSE TO SABOTAGE

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ABSTRACT
Presently, there is no reason to believe that sabotage of radioactive material shipments poses an imminent threat to public health and welfare in the US. The scenarios commonly thought of as "sabotage acts" range from violent protests of a shipping campaign to the capture of a shipment for the purpose of carrying out some terrorist action. The resources required to execute these scenarios vary widely, as does the difficulty in attacking the materials and packagings when shipped by rail, highway, air, or water.

Because the threat of sabotage acts cannot be considered absolutely negligible, efforts have continued to provide appropriate safeguards for some classes of radioactive materials in transportation. Of special concern are those materials perceived to have particularly grave consequences if they are not safeguarded from reasonable threats. In particular, Nuclear Regulatory Commission (NRC) regulations require safeguards on spent fuel in transport. A State of Nevada Petition to the NRC seeks to make these requirements even more stringent.

The Department of Energy (DOE), in its Draft Environmental Impact Statement (DEIS) for the Yucca Mountain Project, evaluated the potential impact of a particularly severe hypothetical sabotage attack on a spent fuel cask in transit.

The consequence analysis in the DEIS examined data obtained in experiments conducted by Sandia National Laboratories in the early 1980s. The projected release fraction obtained for the DEIS was consistent with the results from a more recent experiment performed in France that also used depleted uranium oxide (DUO_2) as a surrogate for spent fuel in a nine-assembly storage/transport cask.

While the surrogate spent fuel source term appears to be reasonably well defined for the type of high energy density device (HEDD[1]) used in the experiments to date, the behavior between spent fuel and DUO_2 surrogate remains uncertain. This amounts to as much as a factor of 10 in the ratio of the aerosol that would be produced by a HEDD released against real spent fuel to that produced by a DUO_2 surrogate (a factor usually termed the SFR). Reducing this uncertainty is the subject of an international cooperative proposal developed among US, German, and French laboratories and agencies to definitively estimate the comparative response of spent fuel and surrogate configurations to HEDD

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* Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94-AL85000.

1 A device that uses the energy produced by a high explosive or propellant to produce a high kinetic energy mass with penetration capability.

interactions. This paper describes the current understanding of HEDD interactions and the additional experiments that are proposed or underway.

INTRODUCTION

There is no reason to believe that sabotage of radioactive material shipments constitutes an imminent threat to the public health and welfare in the US at the present time. The scenarios commonly thought of as "sabotage acts" range from violent civil disobedience protesting a shipping campaign to the capture of a shipment for the purpose of carrying out some terrorist action. The resources required for executing one of these scenarios vary widely, as does the potential difficulty in attacking the variety of materials and packagings that may be shipped by rail, highway, air and water.

Because the threat of sabotage acts cannot be considered negligible, there are continuing efforts and initiatives to safeguard some classes of radioactive materials in transportation. The materials of special note are those for which loss of authorized control might lead to serious consequences, even if only a small amount were lost. For example, the Department of Energy (DOE) places stringent requirements on nuclear weapons shipments. The regulations of the NRC require safeguards on spent fuel in transport. A State of Nevada Petition to the NRC seeks to make the safeguards requirements for spent nuclear fuel even more stringent[1].

The DOE, in its Draft Environmental Impact Statement (DEIS) for the Yucca Mountain Project[2], evaluated the potential consequences of a severe hypothetical sabotage attack on a spent fuel cask moving fuel to a possible repository at Yucca Mountain. The consequence analysis in the DEIS was based on a reexamination of data obtained in experiments conducted by Sandia National Laboratories[3] in the early 1980s. The reexamination[4] used these experimental results and extended them by modeling and extrapolation techniques to include:

- effects of releasing fuel rod pressurization gases
- release fractions derived from a "swept volume" concept
- swept volumes from computer code analysis on the effects of a high energy density device (HEDD)
- respirable aerosol created within the cask that could be swept out by released plenum gases, and
- consideration of estimates for the ratio of aerosol produced by spent fuel to that produced by a depleted uranium oxide (DUO_2) surrogate (SFR) in a similar experimental configuration.

The projected release fraction obtained for use in the DEIS is consistent[5,6] with the results from a more recent experiment performed in France under the sponsorship of the GRS[7] when differences in cask free volume and plenum gas release are considered. The three GRS experiments used DUO_2 as a surrogate for spent fuel in a nine-assembly storage/transport cask.

While the surrogate spent fuel respirable source term appears to be reasonably well defined for the specific type of HEDD used in the experiments to date, only a central estimate for SFR with a factor of 10 uncertainty is available. This makes estimating the potential consequences of a HEDD attack on a spent fuel cask uncertain. To improve the understanding of the potential consequences of a HEDD attack on a spent fuel shipping cask, there are three basic areas that could conceivably benefit from further research:

- HEDD interactions with different cask and fuel types
- SFR values
- HEDD configuration variations

Past experiments of HEDD interactions have treated at least five different cask and cask-like configurations, each containing surrogate spent fuel pins or assemblies. Results among the experiments for a given HEDD type are consistent. Therefore, experiments with additional cask configurations are not currently of primary interest.

The second area of research is quite important because it links aerosol source term data for HEDD experiments that used surrogate spent fuel to what might occur in a similar situation involving interactions with real spent fuel. Preparations for these experiments are covered briefly in this paper and in greater detail in another paper in this session. That work is the subject of a international cooperative proposal developed among US, German, and French laboratories and agencies which is aimed at getting more definitive estimates of the SFR for situations that are reasonably close to those likely to be seen in HEDD interactions with spent fuel.

Sandoval evaluated the relative effects of various types of HEDDs in preparation for his experimental program conducted in 1982. These experiments led to the definition of a particular family of HEDD that is referred to as HEDD Type A. All experiments involving HEDD interaction with surrogate spent fuel that have been conducted to date have used HEDD Type A devices. Since other HEDD types are known to produce effects on materials and structures that are significantly different from those produced by HEDD Type As, the examination of HEDD configuration variations is an area calling for future experiments.

The remainder of this paper addresses HEDD configuration variations.

HEDD EVALUATIONS

HEDDs can be classified into three basic categories:

- HEDD Type A – explosive energy is concentrated in a very slender penetrator moving at speeds in excess of 2 km/s
- HEDD Type B – explosive energy is concentrated in a less slender penetrator at relative velocities around 2 km/s
- HEDD Type C – explosive energy is imparted to a penetrator that is wider than it is long at relative velocities up to 2 km/sec

Experimental work to date with surrogate and actual spent fuel has used HEDD Type A devices. The range of input energies of these HEDD Type A devices has varied over about three orders of magnitude. In a HEDD Type B experiment, a relatively small material sample is projected at a significantly larger target or a flat disk of material is projected at a smaller or larger target. HEDD Type B events may be characterized as ballistic in nature.

HEDD Type Comparison Tests – To evaluate the relative penetration capability of the three types of HEDDs, a series of tests was carried out in which only the total mass of the HEDD was constrained. HEDDs of the three types were selected to cover a range of HEDD types. In addition to equal total mass, the devices were designed with the same outer dimension. Other design features of the three test devices were intended to enhance the potential of the device to penetrate a mild steel target. The test set-up is shown in Figure 1.

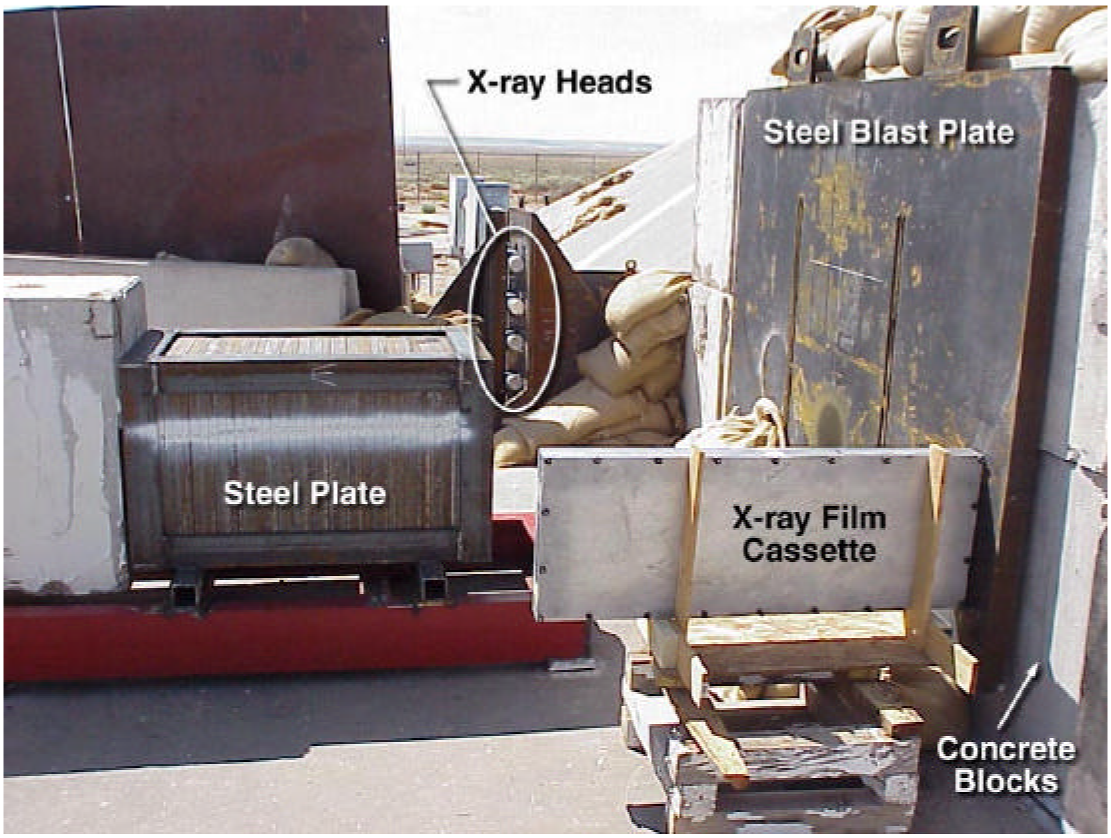

Figure 1, HEDD Test Set-Up.

The three types of HEDDs were tested against a steel target consisting of mild steel plates held together in a welded frame. Concrete blocks were placed on three sides of the HEDD, and a steel plate with a hole to permit the penetrator to pass through was placed in front of the HEDD. The blocks and steel plates were designed to stop fragments from the HEDD and minimize blast. X-ray measurements were made of the penetrator in flight to obtain velocity and dimensional data. Post-test inspection of the steel target plates indicated penetration depth as well as volumetric information.

Results of the three tests were:

- HEDD Type A had the greatest penetration depth, with a relative penetration of 100.
- HEDD Type B's relative penetration was 12-13.
- HEDD Type C's relative penetration was less than 2.

The figures below give some idea of the relative performance of the devices on an identical target that was composed of a stack of mild steel plates. The pictures are of the first plate in each target.

Figure 2, First Plate Penetrated from a HEDD Type A Experiment.

Figure 3, First Plate Penetrated from a HEDD Type B Experiment.

Figure 4, First Plate from a HEDD Type C Experiment

<u>Other HEDD Tests</u> – Also tested as part of this effort were military-type weapons that are occasionally mentioned as potential sabotage tools. To evaluate their relative

effectiveness, several types of devices were tested for penetration of the same type of mild steel target used in the tests described above.

The first configuration tested was the M-430 Grenade, which can be fired from a 40 mm cannon. This device fits in the HEDD Type A category. Figure 5 shows the test set-up and Figure 6 shows the results from this experiment. Relative penetration (compared to the HEDD tests discussed above) was between 5 to 7.

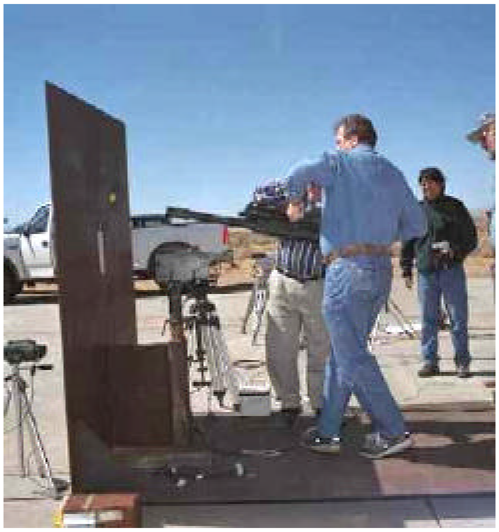

Figure 5, Test Set-Up for Model Mark 19 Grenade Launcher

Figure 6, First Plate Penetrated with M-430 Grenade

The second configuration used several types of 50 caliber armor piercing munitions. This type of penetrator would be a HEDD Type B. Figure 7 shows the test set-up and Figure 8 shows results from this test. Relative penetration ability in the same scale given above would be about 4.

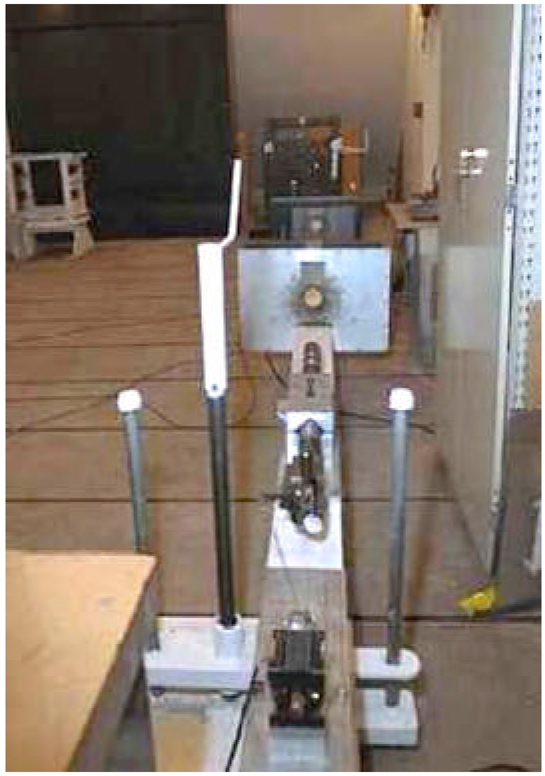

Figure 7, Test Set-Up for the Armor Piercing Munition Test

Figure 8, First Plate Penetrated with Armor Piercing Munition

SUMMARY
The experiments reported here were undertaken to help define the relative penetration capability of various types of HEDDs and to answer questions about the response of certain materials to some military type munitions. Based on these investigations, it appears that devices falling in the HEDD Type A class should receive continued emphasis in future work.

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